Dental Curing Lights

USAF Dental Investigation Service

Overview

- Light-curing basics
- Energy sources
- Energy application
- Factors affecting cure
- Maintenance

Characteristics of Light

- Visible light
  - 400-700 nm
- Most composites sensi
  - 400-520 nm (blue)
- Photo-initiator in resin
  - absorbs photon energy
  - combines with activator
    - amine
  - creating free radicals
    - initiates polymerization

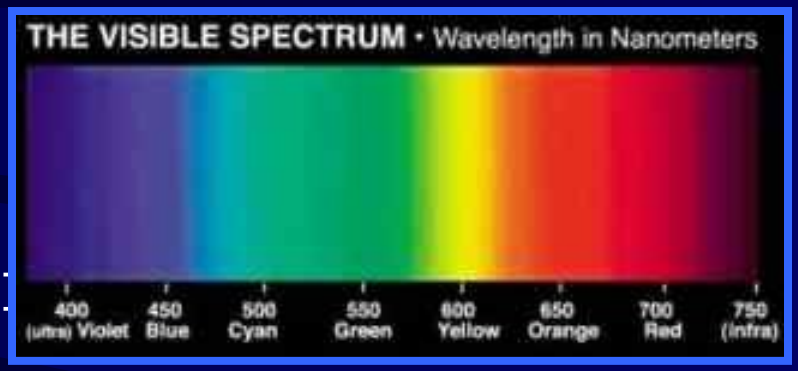
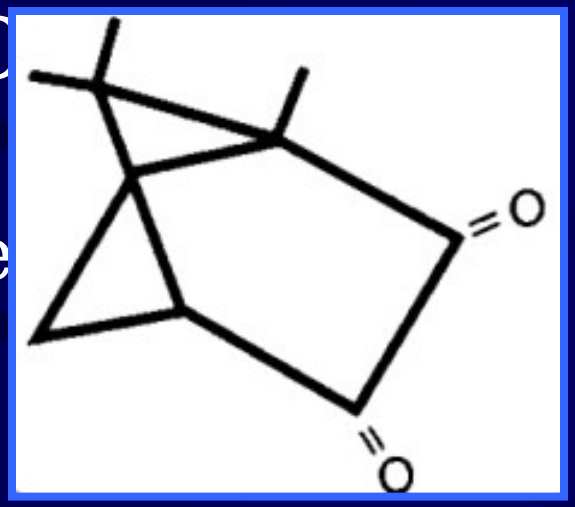
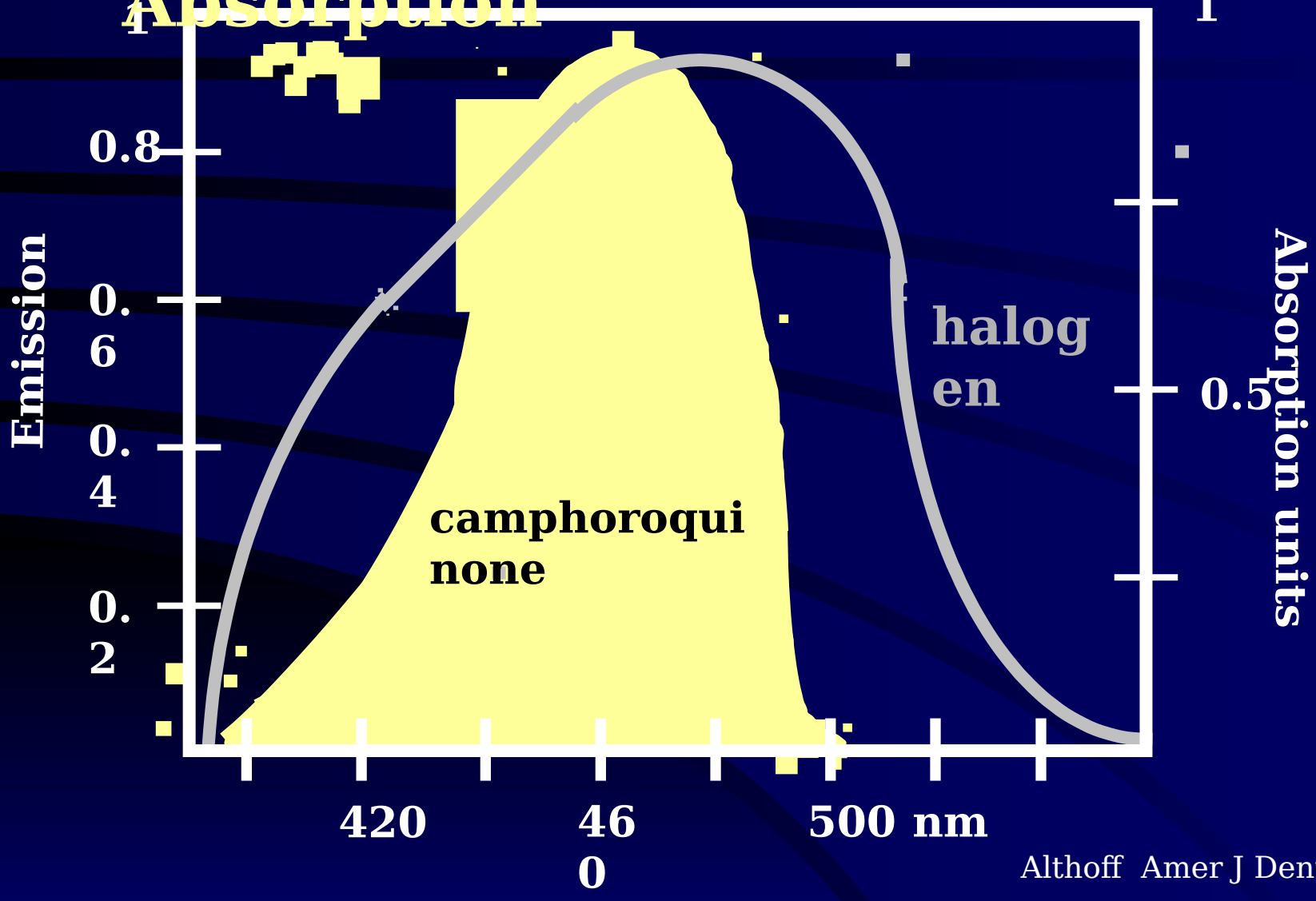


Photo-polymerization

- Camphoroquinone (C
  - most common photo-absorbing mate
  - maximum sensitivity
    - blue range (465 nm)



Spectral Emission / CQ Absorption



Althoff Amer J Dent 2000

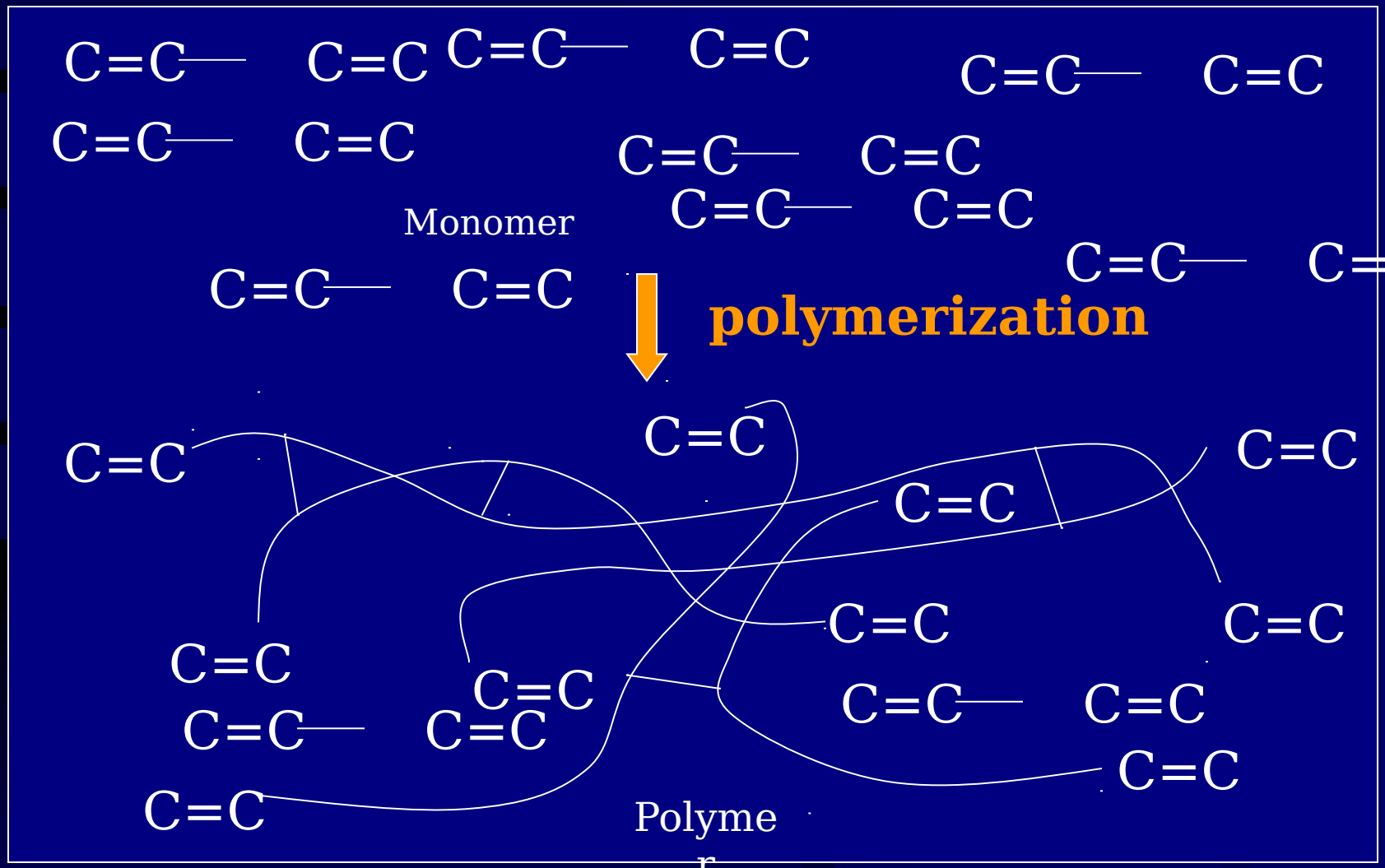
Visible-Light Activation

- Photo-initiator reacts with amine activator
- Forms free radicals
- Initiates addition polymerization
  - monomer
    - Bis-GMA

Polymerization

- Initiation
  - production of reactive free radicals
  - chemical, light, heat
- Propagation
  - monomer units
  - polymer network
- Termination

Polymerization



Ferracane

Photo-polymerization

- Many light curi
  options
  - halogen
  - plasma-arc
  - laser
  - LED

Quartz-Tungsten-Halogen

- Most common dental curing light
- Quartz
  - encasing structure
  - crystalline
  - heat resistant
- Tungsten
  - filament coil
  - flow of electricity

Quartz-Tungsten-Halogen

- Halogen gas
  - protects filament
    - oxidation
  - re-deposits tungsten to filament
    - “halogen cycle”

Quartz-Tungsten-Halogen

- Radiant output
  - infrared energy (IR
    - heat
- Cooling critical
  - do not turn off fan
    - halogen gas lost
    - oxygen enters
    - bulb life dramatically decreases

Quartz-Tungsten-Halogen

- Filters
  - band-pass
    - restricts broader light to narrow blue light
      - 400-500 nm
      - range of photo-initiators
  - 99.5% of original radiant energy filtered
    - inefficient

Quartz-Tungsten-Halogen

- Filters
  - dichroic
    - silver reflective surfa
    - passes IR energy
    - reflects visible light
    - provides focal spot
- QTH bulb
  - 30-50 hours useful life

Plasma-Arc (PAC)

- Two tungsten electrodes
  - small gap
- Pressurized cham
  - xenon gas
- High-voltage spar
  - ionizes gas
    - plasma

Plasma-Arc (PAC)

- High levels of IR and U
  - extensive filtering
    - down to 400-500 nm
  - remote light source
    - liquid-filled light cord

Plasma-Arc (PAC)

- High irradiance
  - > 2000 mW/cm^2
  - claim 1-3 sec cure
- Expensive
  - bulbs >$600
  - may be hard to replace

Argon Laser

- High energy
  - coherent, non-divergent
  - non-continuous
- Very expensive
- Warning signs required

Light-Emitting Diodes (LED)

- Semiconductors
  - electrically-excited atoms
- Gallium-nitride blue
- Narrow emission spectrum
  - 430-490 nm
    - peak at 470 nm
    - near absorption max of camphoroquinone
    - efficient

Jandt Dent Mater 2000

LED Curing Lights

- Long lasting light source
  - minimal aging
  - minimal decrease in outp
- Less lateral heat production
  - minimal or no fan necessary
- No filters
- Typically cordless

Duke Compendium 2001

LED Curing Lights

- First generation
  - high cost
  - low irradiance
    - < 300 mW/cm^2
    - increase exposure t

Leonard J Esthet Rest Dent 2002

LED Curing Lights

- Second generation
  - lower cost
  - higher irradiance
    - > 600 mW/cm^2
    - similar to halogen

Price J Can Dent Assoc 2003

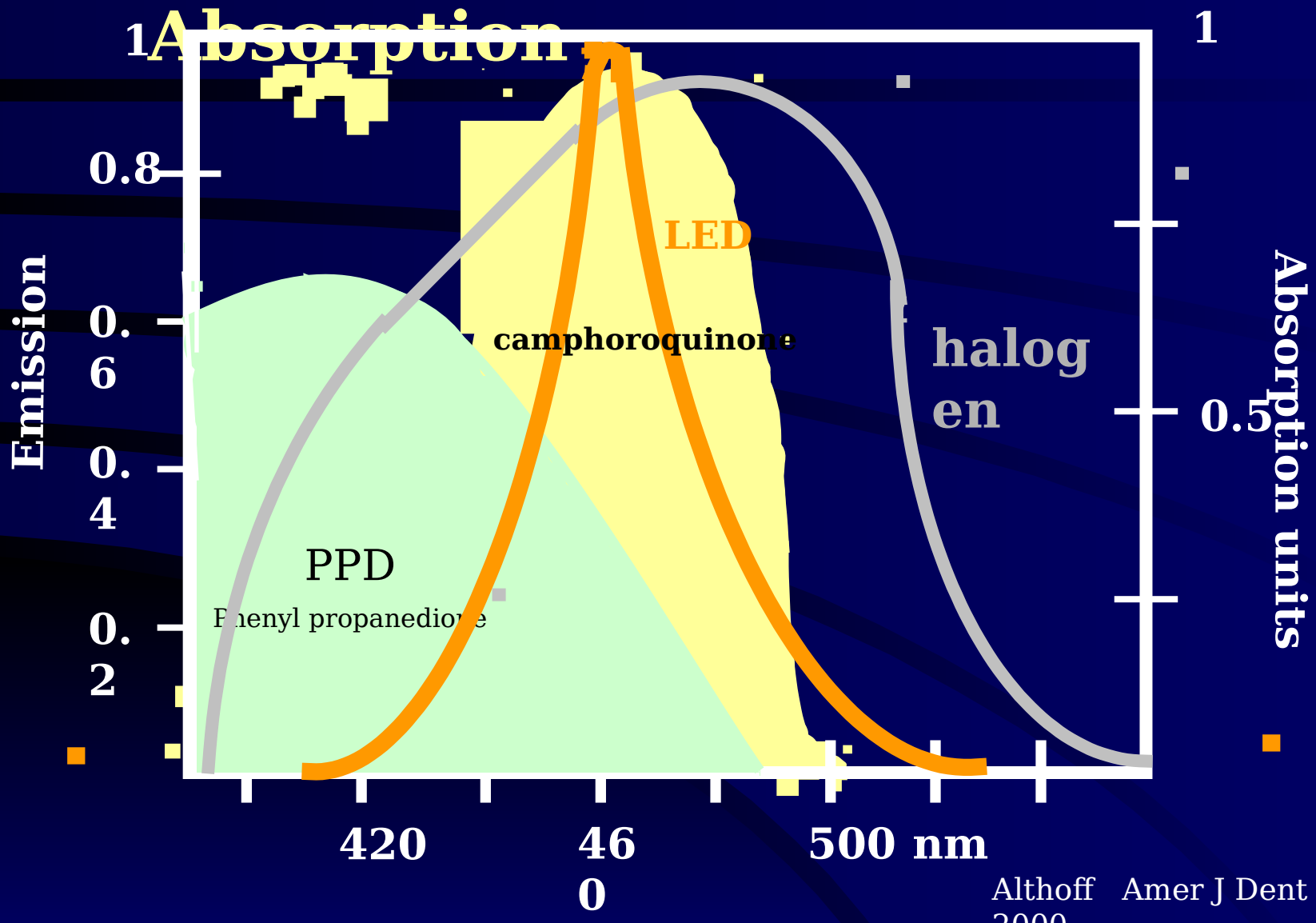
Soh Oper Dent 2004

CRA website: click here for det

New Developments

- Narrow spectrum lights
  - argon laser
  - LED
- Other photoinitiators absorb at lower wavelengths
  - PPD
  - TPO
- Narrow spectrum lights may not polymerize materials containing other initiators

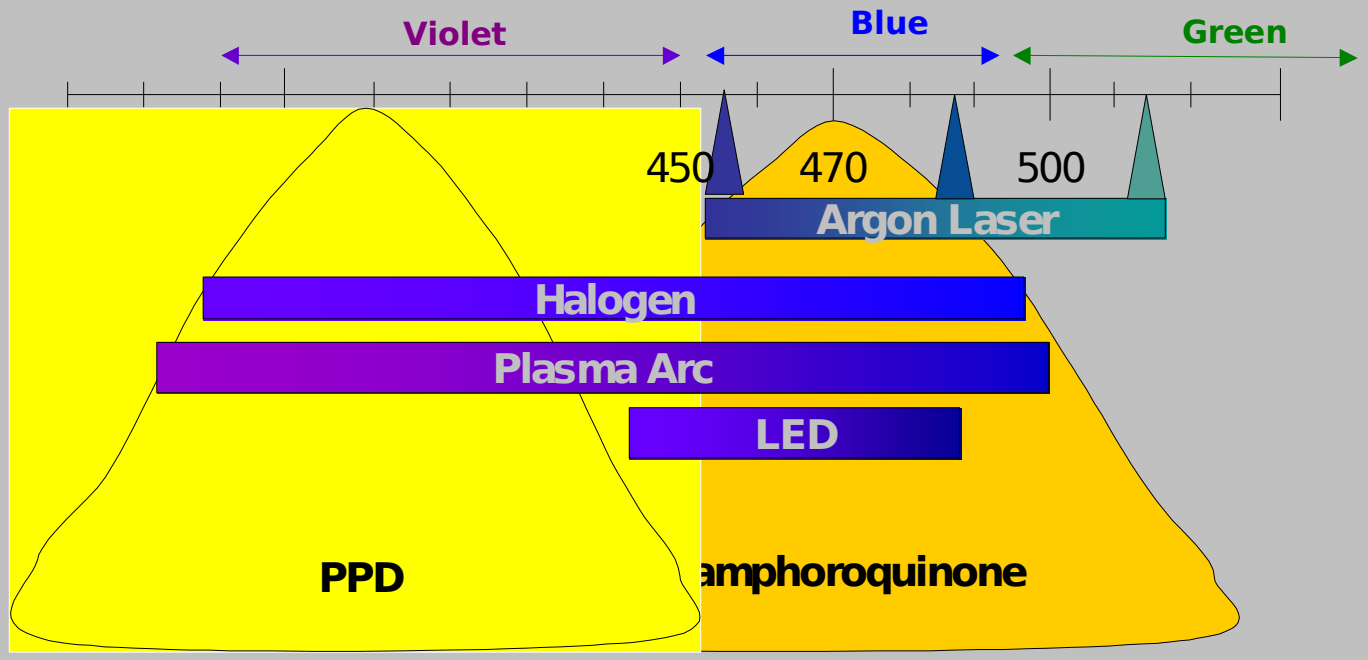
Spectral Emission / Absorption



Althoff Amer J Dent 2000

J . Lindemuth 2003

Photo Initiators & Absorption Spectrum



AADR Abstract 0042 Efficiency of Various Light Initiators after Curing with Different Light-curing Units

P. BURTSCHER, and V. RHEINBERGER, Ivoclar Vivadent, Schaan, Liechtenstein

LED – Resin Incompatibilities

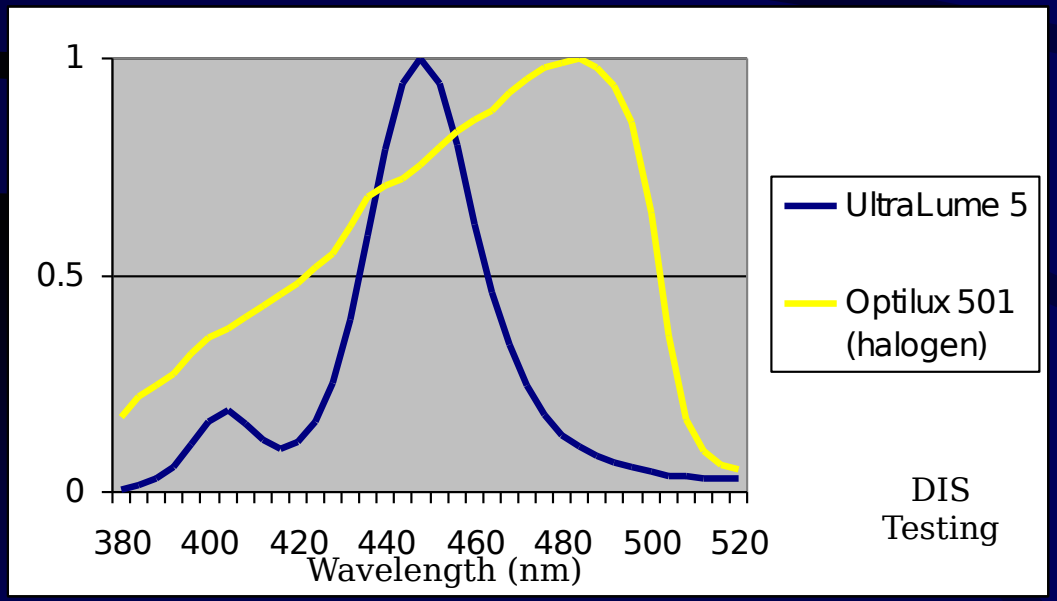
- Products
  - Biscover (Bisco)
  - Cabrio (Discus Den
  - Panavia F (Kuraray)
  - Principle (Dentsply)
  - Pyramid (Bisco)
    - neutral & translucent

Click here for details

CRA Newsletter 2003

Multi-Spectrum LED Light

- UltraLume LED 5 (Ultrad
  - bimodal emission spectrun
    - cures all photo-initiated mat



Palmer JDR 2004 Abstract #552

Click here for abstract

Effects of Energy

- Increased light exposure
  - increased depth of cure
  - increased conversion
    - polymerization
  - increased hardness
  - up to threshold
- Decreased light exposure
  - inadequate polymerization

Halvorson Dent Mat 2002

Inadequate Polymerization

- Lack of retention
- Increased wear
- Color instability
- Microleakage
  - post-op sensitivity
  - caries

Ferracane J Dent Res 1997

How long does it take to adequately cure a composite?

- Depends on
  - energy density
    - irradiance of light x time
  - distance from composite
  - collimation of light
  - wavelengths
    - emitted
    - absorbed
  - composite type

Optimal Polymerization

- Required Energy Density
  - varies from composite to composite
  - based on 2 mm depth
  - based on minimum 80% hardness ratio
    - bottom to top

- Required energy density not provided by composite manufacturers!!

Pilo Dent Mater
1992

Irradiance

- Power (mW) incident upon an area (cm^2)
  - surface area of the tip of the light guide

$$\text{Irradiance} = \frac{mW}{cm^2}$$

- Large tips
  - lower irradiance
- Small tips
  - higher irradiance

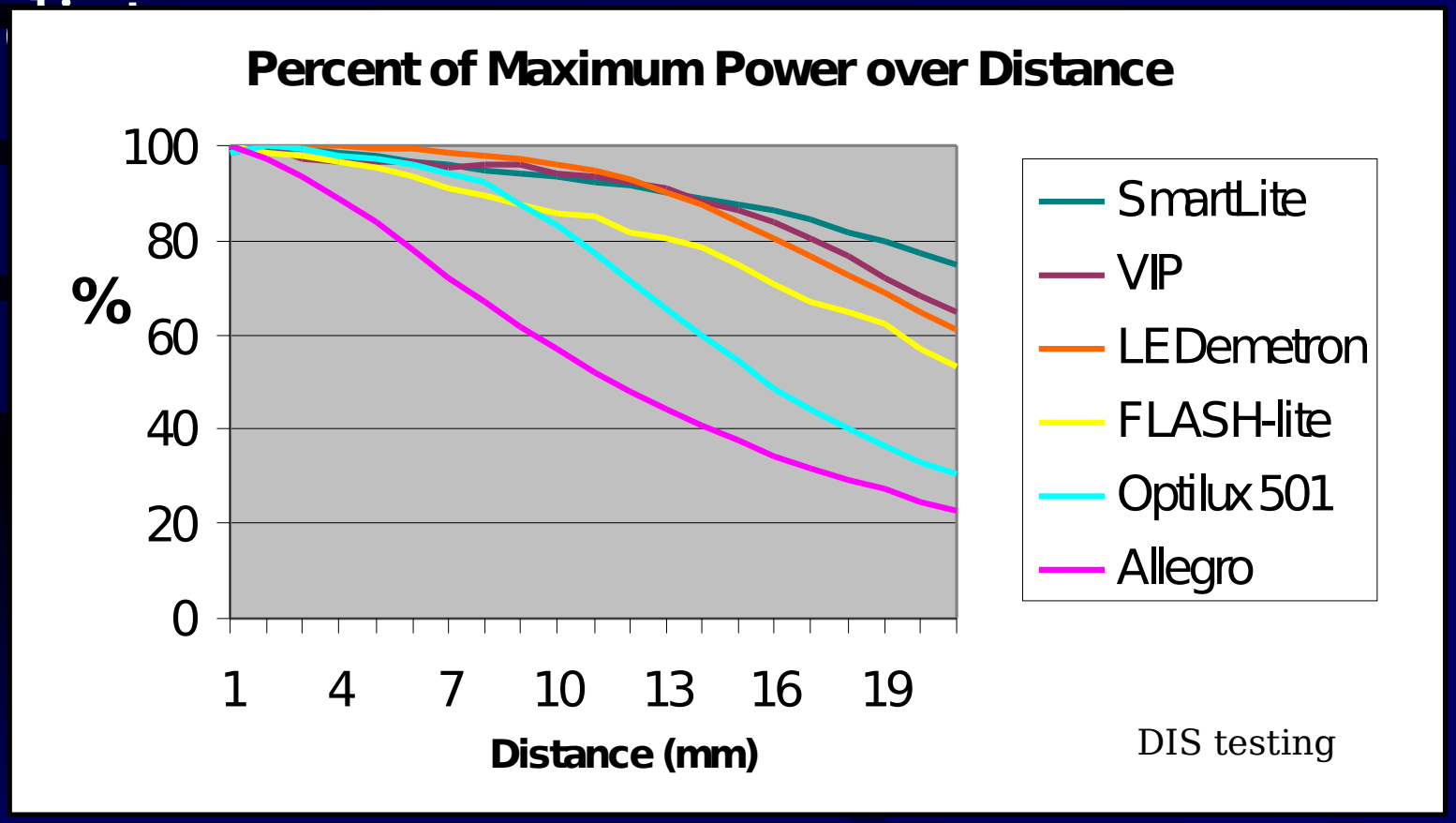
Total Energy Density

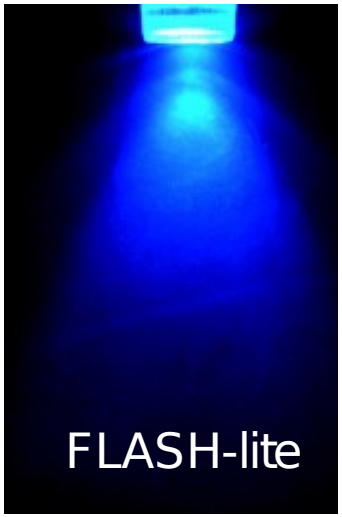
- Irradiance x time
  - mW/cm^2 x sec = mJ/c
- Reciprocity
  - ↑ irradiance ↓ tir
  - ↓ irradiance ↑ tir

Halvorson Dent Mat 2002

However, curing distance affects cure

- Collimation of light critical at greater





Light Projections

DIS Evaluations 2004

Collimation of Light

- Collimation
  - type of light guide
    - fiberoptic
    - acrylic
    - simple aperature opening

Collimation of Light

- Collimation
  - focusing power
    - turbo (tapered) tips
      - increase irradiance at tip
      - but may decrease irradiance over distance

10/10 mm standard tip

13/8 mm turbo tip

Price J Esthet Dent 2000

Click here for abstract

Type of Composite

- Microfills scatter light
- Darker shades impede energy transmission
- Glass fillers transmit light better
- hybrids > flowables

Kawaguchi JDR 1994

So, how long should I cure my composite?!

Refer to the manufacturer's instructions for guidance

- Increase curing time
  - lower irradiances
    - LED
    - Halogen
  - microfill composites
  - darker shades
  - flowable composites
  - greater distances
  - poor collimation
- Decrease curing time
  - higher irradiances
    - Plasma arc
  - hybrid composites
  - lighter shades
  - close distance
  - good collimation

Click here for minimum cure times

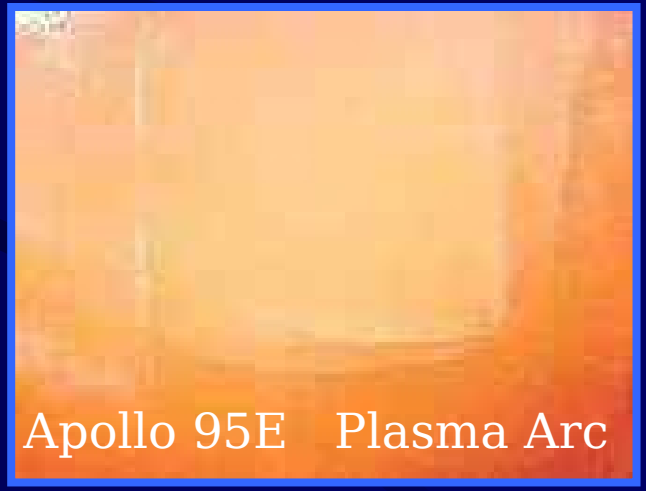
Curing Test Kits

- Scrape tests
  - depth of cure
    - may overestimate
  - individualized
    - composite
    - light
    - curing time

Click here for details

Why not just use high irradiance?

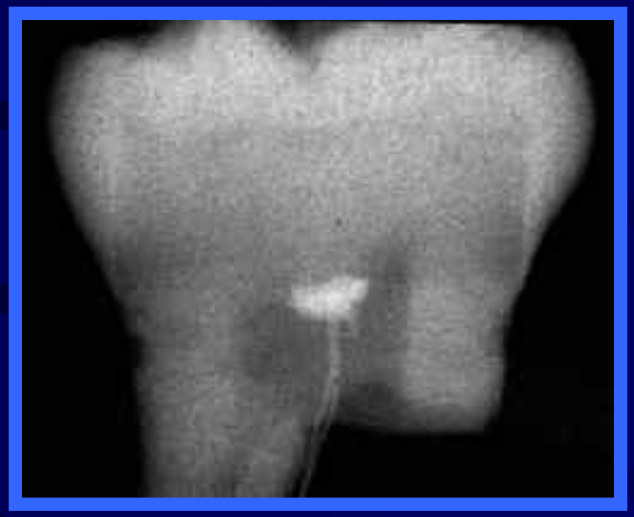
- Higher temperatures
- Accelerated polymerization shrinkage?
  - stress?
    - cracks, crazing?



3 seconds

Heat Emission from Light Tip

- Multiple factors
  - irradiance (power)
  - curing time
  - light collimation
  - curing distance
  - type of light guide



Vandewalle JDR 2004

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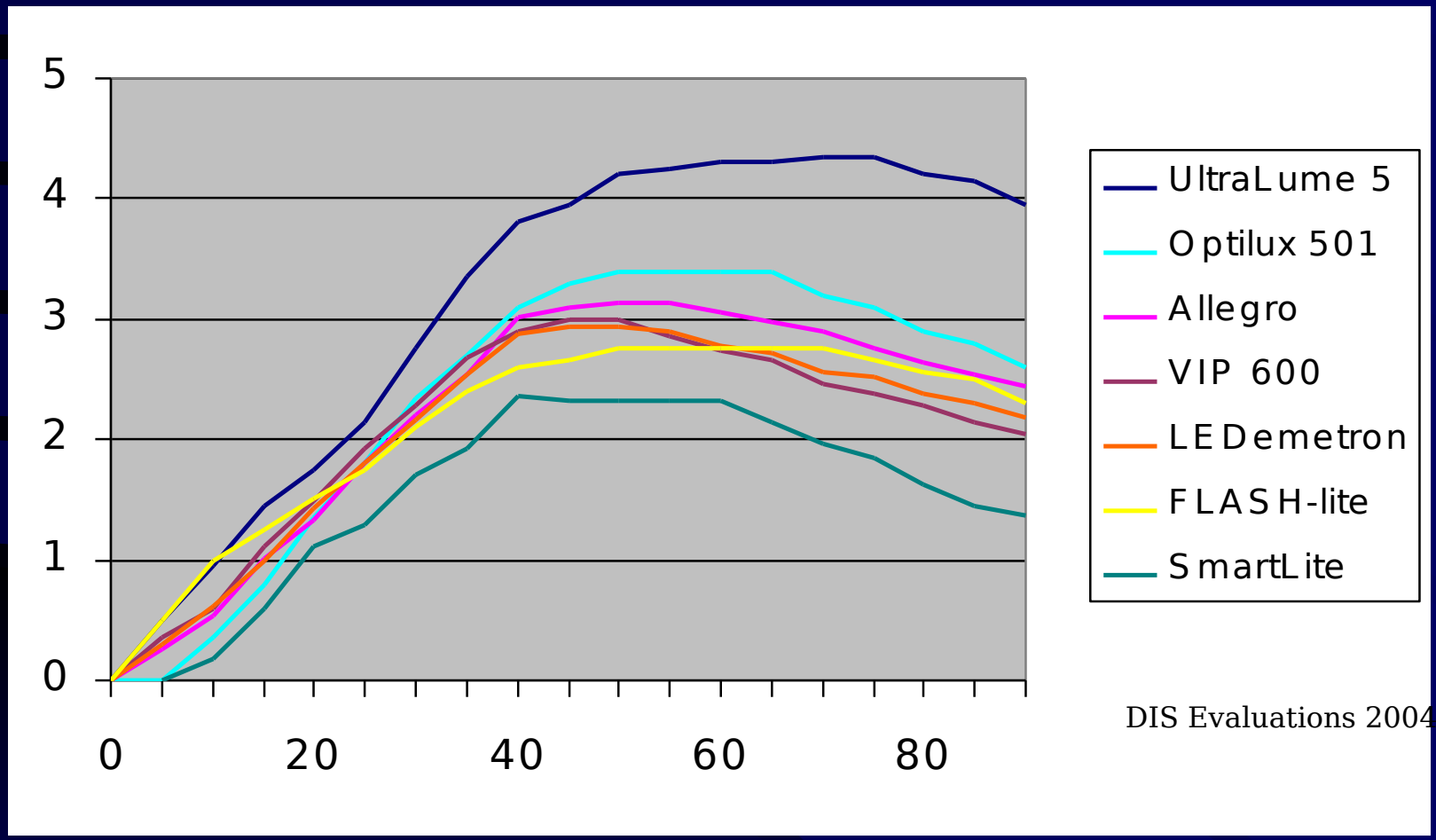
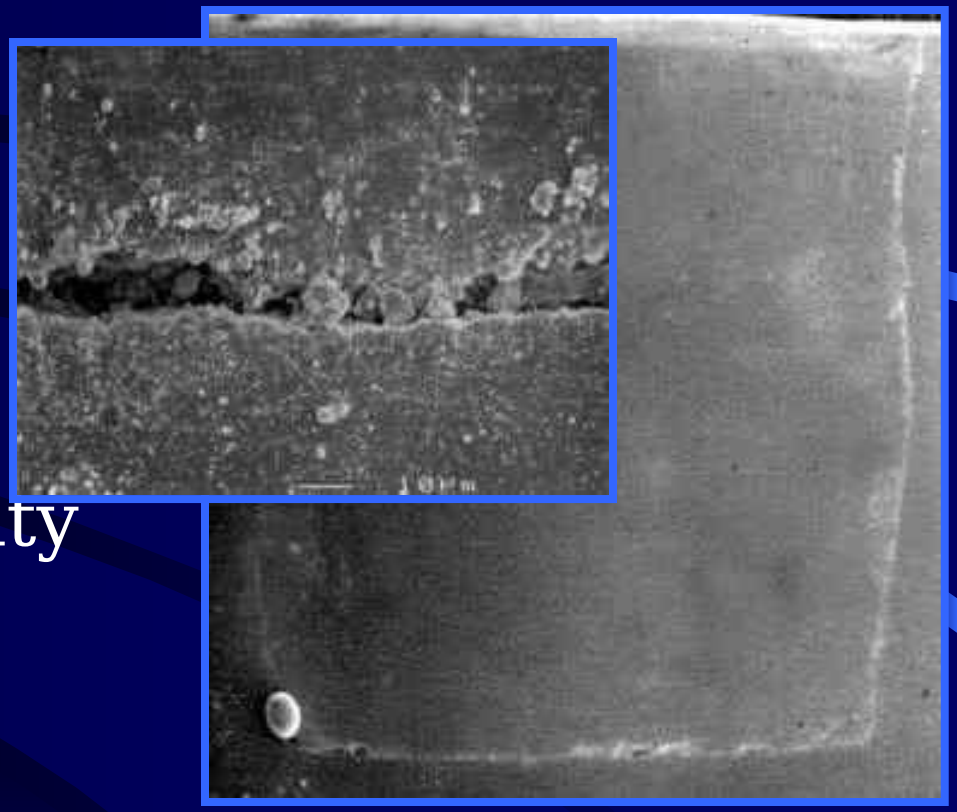
Increase in Temperature
(pulpal)



DIS Evaluations 2004

Polymerization Shrinkage

- 1.5-7 % volume
- Open margins
  - microleakage
  - staining
  - post-op sensitivity



Early Polymerization

- Cross-linking relatively limited
  - flows fairly easily
  - accommodate stresses
    - no damage to adhesive bo

Further Polymerization

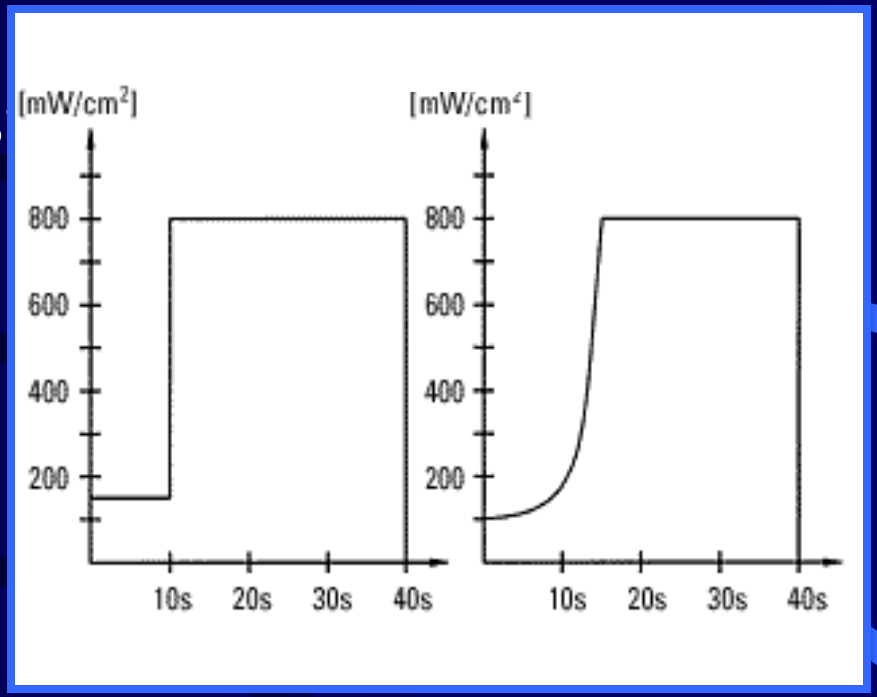
- Flow decreases
- Stiffness increases
  - stress increases
  - can cause adhesion failure
- Bond strength must exceed contraction stress
  - stable marginal adaptation

“Soft-Start” Polymerization

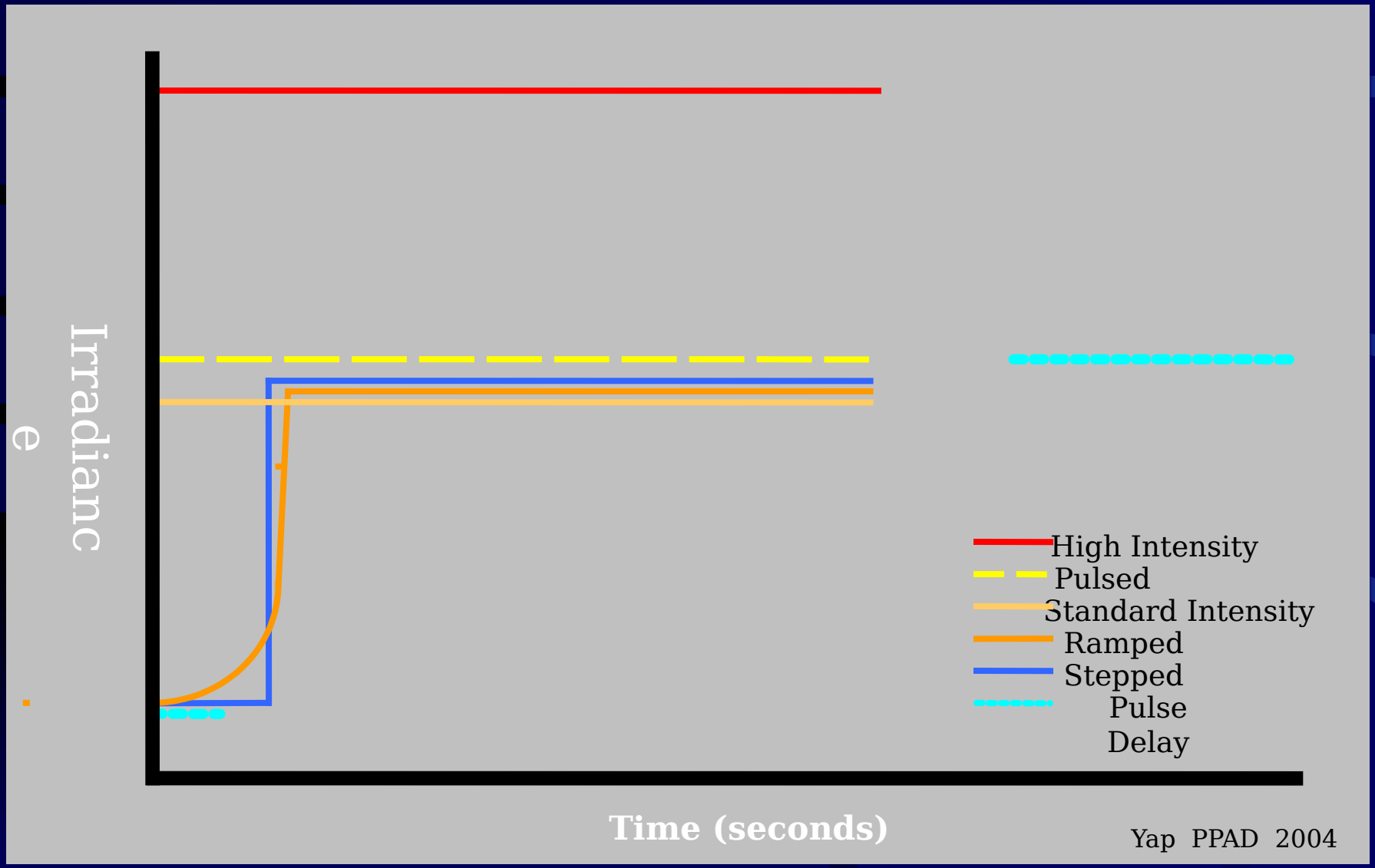
- Slow increase or delay in irradiance
- Slow rate of shrinkage
  - reducing stress
- Feature provided with some curing lights

“Soft-Start” Polymerization

- Stepped
  - short, low initial burs
  - full intensity
- Ramped
  - gradual increase from initial low level
- Pulsed delayed
  - short, low level burst
  - delay for polishing
  - full intensity



Curing Regimens



Yap PPAD 2004

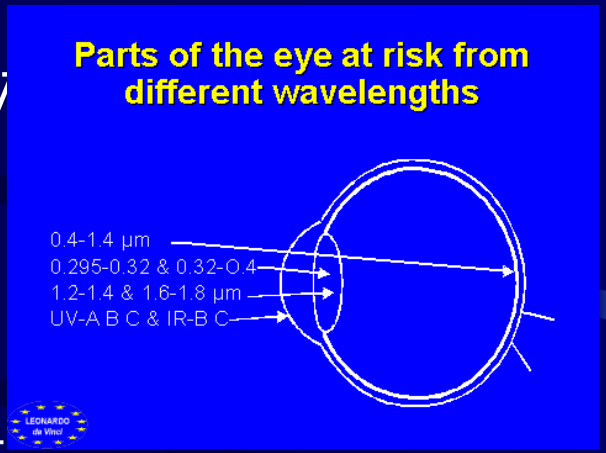
“Soft-Start” Studies

- Laboratory studies somewhat equivocal
  - many show benefit
  - some show no improvement
- Clinical studies are limited
  - all show NO BENEFIT!
    - El Mahdy J Dent Res 1999
    - Oberlander Clin Oral Investig 1999
    - Brackett Oper Dent 2002
  - more clinical studies are needed

Click here for details

Optical Hazards

- Halogen laboratory study
  - ACGIH guidelines
  - No thermal hazard
  - Unlikely photochemical ha
    - stare directly for > 2.4 minutes
    - 25 cm distance
- More research is needed!



Satrom JDR 1987

Click here for abstract

Optical Safety

- Do not look directly at light
- Protection recommended
  - glasses
  - shields
- May impair ability to match tooth shad

Maintenance

- Periodic visual inspection of unit
  - light guide
  - filters
  - bulb
- Check irradiance
  - radiometer

Contamination of Light Tip

- Reduces passage of lig
- Reflects light
  - increases heat build-up
  - shortens bulb life
- Remove debris
  - polishing kit
  - blade
  - replace light guide

Integrity of Filters

Halogen

- Designed to select for blu
- Can crack
  - dropped or overheated
- Coating prone to delamin
- Ineffective filter
  - scatters rather than transmits light

Quality of Light Source
Halogen

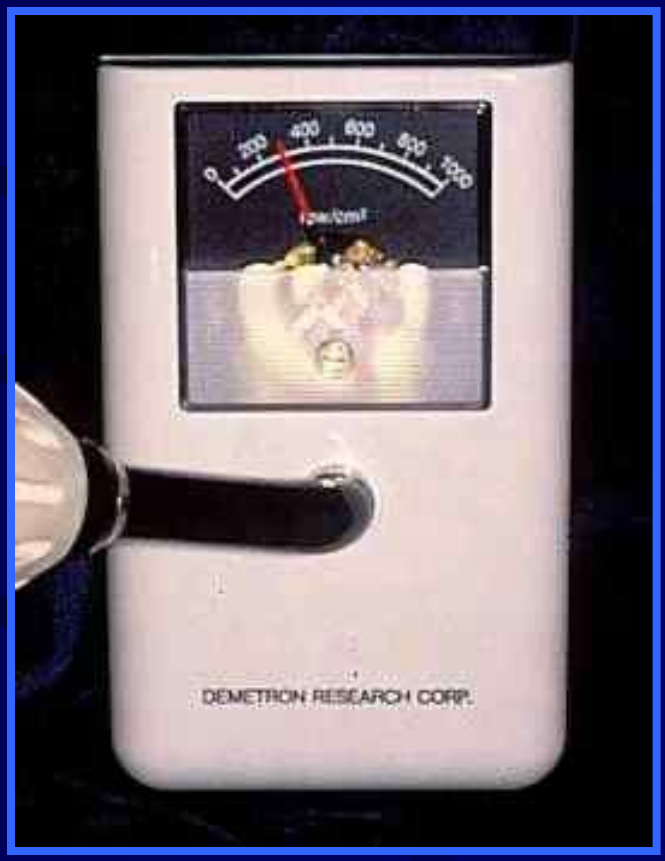
- Blue intensity decreases
  - before brightness drops of
- Fogging cuts output
  - 30 - 40%
- Bulb silvering
  - discoloration of internal glass
  - black oxides
    - diminish light output
  - mirror becomes less reflective

Radiometer

- Consists of photosensitive diode
  - specific for light
- Measures useful light output at curing tip
  - hand-held
  - built-in
- Light-specific radiometer
  - halogen
  - LED

Hand-held Radiometers

- Numerical
  - analog
  - digital



Built-in Radiometers

- Indicator ligh
  - range type
- Numerical

Radiometer Study

- Radiometer
  - poor indicator of actual irradiance
- Degree of inaccuracy va
  - based on the diameter of tip being measured
    - larger tips may overestimate
    - smaller tips may underestimate

Leonard Oper Dent
1999

Click here for details

Radiometer Recommendations

- Initial baseline irradiance
- Compare to subsequent irradiance values
  - at least weekly
  - use the same diameter tip
  - keep a log

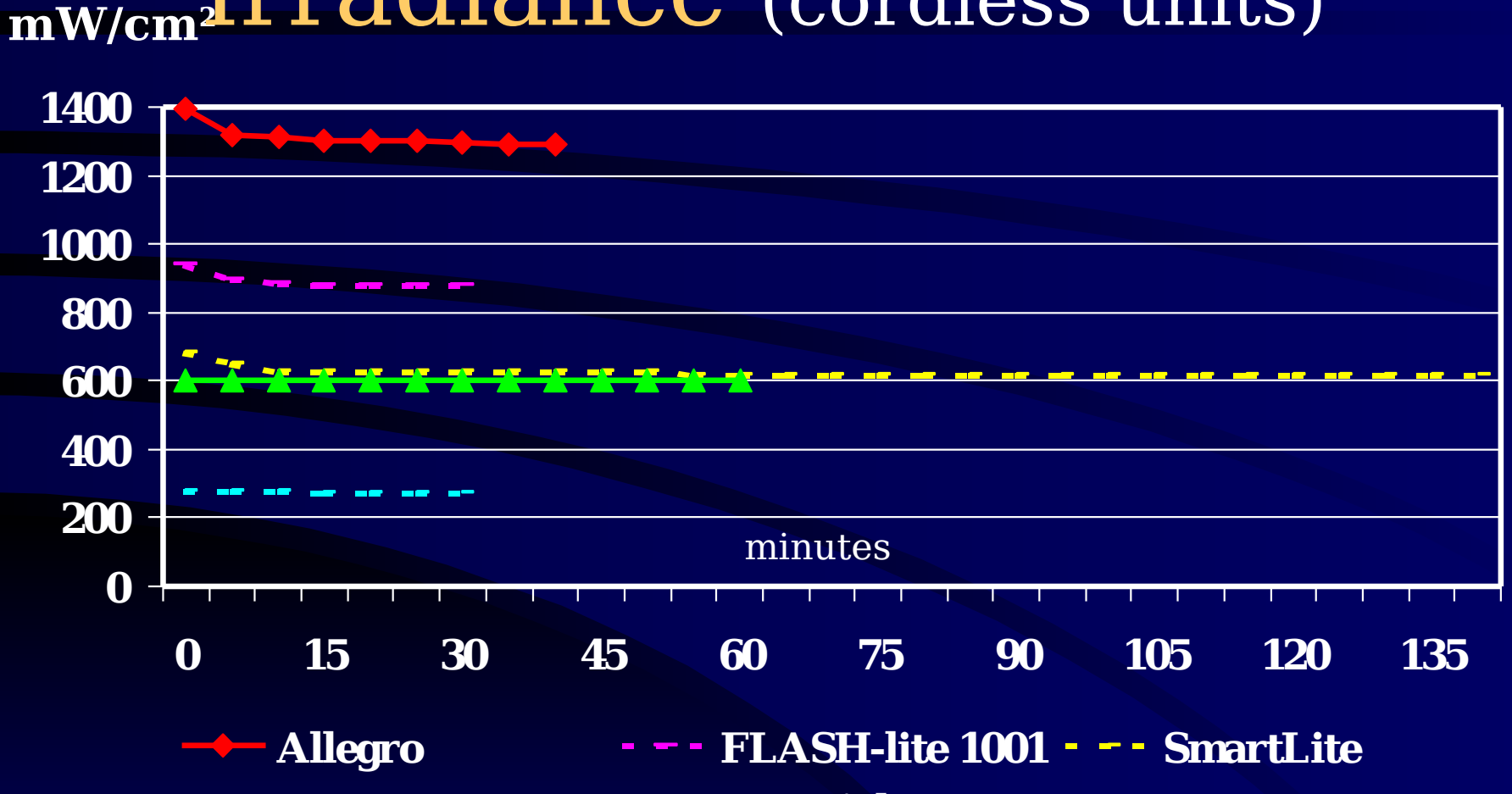
Radiometer Recommendations

- If irradiance drops
  - inspect
    - light guide tip
    - filter (if applicable)
    - light source
    - battery depletion (if applicable)

Cordless LED Lights

- LEDs consume less energy
  - – most newer units maintain irradiance
    - over length of discharge

Discharge Time on Irradiance (cordless units)



DIS Evaluations

Purchasing Considerations
Federal Service

- Halogen
  - established technolog
  - relatively inexpensive
  - multiple curing mode
  - poor efficiency
    - heat
    - fan
  - limited bulb life

Purchasing Considerations

Federal Service

- LED
  - similar curing to haloge
  - lightweight and quiet
  - longer LED “source” lif
  - more efficient
    - less lateral heat
      - little or no fan necessary
  - may not polymerize all photo-initiated materials
  - batteries may have to be replaced

Click here for Synopsis of 2nd generation LED curing lights

Purchasing Considerations
Federal Service

- Plasma Arc
  - shorter curing times
  - more expensive
  - higher heat potential
- Argon Laser
  - very expensive
  - excellent collimation
  - impractical for routine use

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